On a new Form of "Ghost" Micrometer. By Chas. E. Burton, Esq., and Howard Grubb, Esq.

In the present Note an arrangement for using the images of fixed or moveable lines in the measurement of images, formed by the objective of a telescope microscope or spectroscope, instead of the material lines hitherto generally employed, is described, and several methods of applying them are indicated.

It is well known that the ordinary wire micrometer is unsuitable for the measurement of two classes of objects, namely, planetary disks, and double stars which are near the limit of separability for the object glass employed when direct measurement is attempted. The difficulties attendant on its use in the cases above mentioned are briefly these:—(1) On bringing a material line in contact with the image of a luminous body of sensible magnitude, diffracted light appears on the side of the wire furthest from the image to be measured; (2) If a wire be placed on the image of a star, that image becomes elongated in the direction perpendicular to the wire. Defect (1) renders it extremely difficult to ascertain when a micrometer wire is accurately in contact, *e.g.* with the limb of a planet; and Defect (2), by reason of the interval between the components of an extremely close double becoming filled with light, when the wires are placed on the components, renders it impossible to obtain direct measures of such objects with the required certainty.

The difficulties above indicated have been treated very completely by Professor Kaiser in vol. iii. of the Leyden Observations, pp. 104–5, where he refers with approval to a proposal by Lamont (*Jahrbuch der K. S. bei München*, Seite 187) to employ "ghost" lines for such measurements; and by the Rev. W. R. Dawes, in *Mem. R.A.S.* vol. xxxv. pp. 153 and 161.*

The suggestions of Prof. Kaiser seem never to have been carried into effect.

In the *Proceedings of the Vienna Academy of Sciences* for 1856, vol. xx. p. 253, H. Karl v. Littrow describes a mode of forming a "ghost" of a system of wires applicable and actually applied to a meridional telescope. In this instrument the ghost lines are interrupted at or near their centres by the interposition

* Since this paper was read before the Society we have been enabled to examine Prof. Lamont's original paper, giving details of the construction of a form of ghost micrometer devised by himself, with which numerous observations of the satellites of *Jupiter* and the ring system of *Saturn* were made. The images of the lines (bright) or holes in a diaphragm were reflected by a glass plate nearly perpendicular to the end of the telescope, through which the stellar or planetary light passed. Professor Lamont's intention was (*loc. cit.*) to get rid of the errors of judgment which are almost or quite unavoidable when the extreme points of the line under measurement are concealed by the wires employed for that measurement. He does not mention the still more injurious effects of diffraction referred to by Mr. Dawes, and in paragraph (2) of this Note. Professor Stämpfer also employed a similar arrangement with much success for meridian work (*Sitz. Berichte Wien. Ak.* Bd. 20, Seite 314).

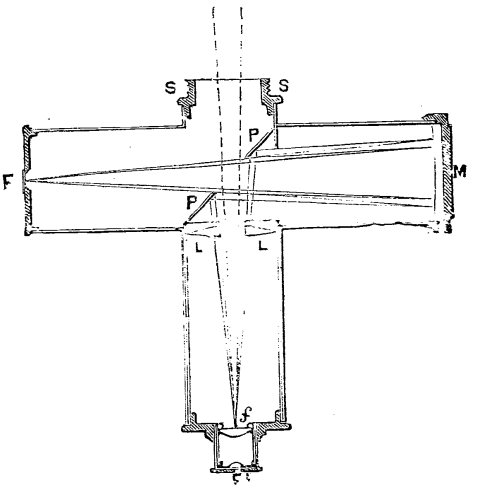
of an opaque bar, and the star is caused to traverse the series of blank spaces thus formed. It does not appear, however, that any attempt was made to adapt this to a position micrometer of an equatoreal instrument.

An instrument somewhat resembling that of Dr. Littrow, and designed for use as a position micrometer, was devised by Mr. G. P. Bidder, and is described by him in the *Monthly Notices* for June, 1874. In this form of ghost micrometer the image of the lines is formed by a unilateral oblique pencil of rays, and it would probably be difficult to avoid loss of definition due to dispersion by the lenses of the eyepiece, as well as to preserve an invariable scale value, on account of the want of a sufficiently rigid connection between the several parts of the instrument. Any movement of the second prism of the optical train, as proposed for the purpose of transferring the system of "ghost" lines to any part of the field, would directly tend to alteration of the scale value and introduce a variable parallax of serious amount.

The instrument now to be described is one of several forms contrived with the object of avoiding the difficulties encountered by those who have hitherto worked at this subject, and of extending the powers of the wire micrometer into the field occupied by the double image micrometer, by rendering the measurement of planetary disks, and close double stars practicable without the production of interference phenomena or the necessity of halving the light of the image, the last being a great hindrance to the use of the double image micrometer in the measurement of faint objects. At the same time the connection between the several parts of the instrument is so rigid and permanent that variation in the scale value will be produced by temperature only, and the corrections thereby necessitated will be of the same order with those already familiar to observers.

The accompanying figure represents the most simple form of the instrument hitherto devised by us, one-third of its actual size. Externally it consists of a pair of tubes, one in the axis of the telescope, and the other at right angles thereto. The first of these tubes is attachable to the draw tube by an ordinary "Tulley" screw at S, and carries at its lower end the eyepiece E. The cross tube carries at one end a "Reticule" or wire frame F, moveable or stationary, according to requirement, and at the other a cell containing a concave silvered mirror M, the radius of curvature of which is slightly greater than the distance between F and M. At the junction of the tubes is mounted (at 45° to F M) a plane silvered mirror P, perforated by an elliptical hole slightly larger than is necessary to allow the pencil of rays from the object glass to pass. Immediately below P is inserted a perforated achromatic lens L, to increase the convergence of the rays from M, and thus diminishing the length of the eyetube while forming an image of F at the focus of the object glass. F being illuminated by a faint external

light, the rays from it pass to M through the hole in P, and, being reflected by M in a cone of smaller angle, are received on the inner edge of P and are thereby diverted into the eye-tube, where they are still further condensed by L and brought to a focus at *f*, the focus of the object glass.



In some cases the lens L may be necessary, and in others it may be found better to use a plane mirror at M and throw the whole work of forming the "ghost" images on the lens L. It is, of course, not necessary that the cross tube should be at *right angles* to the eyetube, and in some cases it may be advisable to use a different arrangement of the parts. If it should prove to be difficult to adapt the instrument to any existing telescope on account of its length (four inches), a Barlow lens can be inserted at S; but some forms of the apparatus have been devised in which there is no cross tube, and the "ghost" images are formed by a perforated concave mirror mounted in a tube capable of being pushed into the draw tube of the telescope. The best form of condensing lens L is under consideration, and it may possibly be found desirable to superachromatise it, to compensate for the undercorrection of the usual eyepieces for lateral pencils.*

In two of its simplest forms, including that represented in the figure, the "ghost" micrometer has been severely tested by one of us, as regards the effect of the images of the lines upon the images of various celestial objects furnished by an equatorially mounted objective of six inches' aperture and six feet focal length. The objects scrutinised for this purpose were the following: lunar details near the terminator and fully enlightened; *Jupiter* and *Saturn* with their satellites; and numerous stars, both single and double. In all cases the result was the same, not the slightest change of form or false light beyond the limb (of the planets) being visible, or even suspected, when the objective images were brought in contact with or were occulted (covered) by the "ghost" lines, powers up to 400 linear being employed whenever definition was suitable. The illumination of the reticules employed was extremely easy, and readily adjusted to suit the brightness of the object observed. It was possible with the direct light of an ordinary candle, unassisted by any optical arrangement for rendering it parallel or convergent, to increase the brightness of the lines sufficiently to make them clearly visible against the brightest parts of the

* Another form has since been devised in which this lens is not required.

Moon's image. The reticules employed were systems of lines cut through an opaque film deposited upon glass.

Suggested forms of "ghost" micrometer, with their applications.

(1) In its most simple form this micrometer will do duty as a transit eyepiece, displaying dark lines on a bright field, or *vice versâ*, and can be fitted with reticules of any kind for mapping groups of stars, or details of the Moon or planets, including of course circles for ring micrometer work.

(2) By substituting for the reticule a wire micrometer with one or two screws, the instrument can be used (*a*) instead of an ordinary uni- or bi-filar micrometer with bright field; or (*b*) as a unifilar micrometer with bright lines cut through an opaque film; or (*c*) as a bifilar micrometer with bright lines, the object lines (at F) being in this case spider webs illuminated by a Wenham paraboloid or other similar contrivance.

(3) By splitting the plane mirror P centrally in the plane M P E, and mounting one half on an axis perpendicular to that plane, attached at its upper end to a lever arm terminating in a sector actuated by an endless screw with divided head, a double set of "ghost" lines might be formed by inclining the two parts of the plane P to one another by a movement of the arm and screw. One of these sets of lines would be stationary, while the other moveable set would have its movement registered by the turns and parts of a turn of the endless screw. Of course the lines might be either dark on a bright field, or bright on a dark field, the latter being best, as in the former case the lines would not be black, but would be of half the brightness of the field. We have experimentally proved that the definition of the lines is unaffected by stopping off half the aperture of M or P in a direction perpendicular to them, and that their brightness does not sensibly diminish for a considerable distance past the centre of the field.

(4) By substituting diaphragms pierced with small circular apertures illuminated by polarised light variable in intensity and colour, this micrometer can be made available for photometric and colour comparisons of stars after the method of Zöllner. Not only can the field, in the case of bright field illumination, be illuminated with light of any desired tint, but if bright lines are employed they can be coloured as the observer may prefer, for there is always a superabundance of light which is yet completely under control. The lines can be shown "broken" or continuous, as may be desired. The first-mentioned arrangement may be advantageous under some circumstances.

A useful modification of the reticule mentioned in a former section would be a bright ring (photographed), divided into degrees and nearly of the same diameter as the field, which would assist materially in estimation of position angle when the faintness of the object viewed rendered *measurements* impossible.*

* This suggestion has been anticipated by Dr. Lamont. *Vide supra.*